Study of Using Natural Rubber Latex as a Filtrate Loss Prevention Additive for API Class G Cement

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Abstract

The main objective of this research is to study the probability of using natural rubber latex (NRL), inexpensive and ecological friendly biopolymer and easily affordable in Thailand, as a fluid loss prevention additive for the API Class G Cement. In this study the API class G cement had been prepared as cement slurry at water/cement ratio (W/C) of 0.5 wt.% and were mixed with natural rubber latex (60% concentrated Latex - High Ammonia) at polymer (NRL) /cement ratio (P/C) of 0.05, 0.10, 0.15, 0.20 and 0.25 The cement slurry samples were casted in the cylindrical mold, moist cured for 7 days, and air cured for 28 days at room temperature, respectively.

The porosity and permeability test were conducted under the Overburden poro-perm cell unit, and results of the tests showed that the porosity and permeability values of the cement samples decreased until the P/C ratio reach 10 wt.% and then they increased steadily. This is because if the P/C ratio is greater than 10 wt.%, the hydration reaction of the mixed cement will take place rather than the polymer coalescence reaction and resulted in the higher polymer flocculant and dispersion. Therefore, the optimal P/C ratio for using the natural rubber latex as a fluid loss prevention additive for the API Class G Cement is 10 wt.%.

Keyword: API class G cement/ Natural rubber latex/ Latex modified cement/ Porosity/ Permeability

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1. Introduction

Primary cementing is the process of placing cement in the annulus between the casing and the formations exposed to the wellbore. Since its inception in 1903, the major objective of primary cementing has always been to provide zonal isolation in the wellbore of oil, gas, and water wells (Smith, 1984), e.g., to exclude fluids such as water or gas in one zone from oil in another zone. To achieve this objective, a hydraulic seal must be obtained between the casing and the cement, and between the cement and the formations, while at the same time preventing fluid channels in the cement sheath (Figure 1).

Fluid loss control agents have been added to well cement slurries for more than 20 years, and it is now recognized that the quality of cement jobs has improved significantly. Indeed, it is generally acknowledged that insufficient fluid-loss control is often responsible for primary cementing failures, because of excessive increases in slurry density or annulus bridging. In addition, formation invasion by cement filtrate may be very damaging and deleterious to production (Bannister and Lawson, 1985; Economides and Nolte, 1987). With respect to remedial cementing, the problem is to adjust the fluid-loss rate to the perforation size and the nature of the formation (Binkley et al., 1957; Cook and Cunningham, 1977). However, for both primary and remedial cementing, very little has been written to justify the level of fluid-loss control required to achieve a good cement job [1].

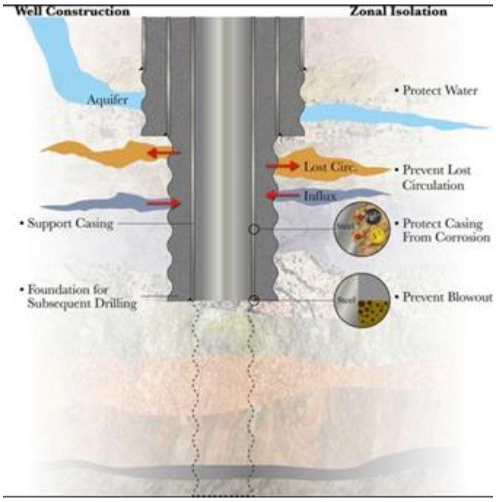

Figure 1. Illustrates the reasons why we cement wells

Nowadays cement mix may be used a chemical as an additive to provide the suitable cement. For example, using polymer as an additive to reduce fluid loss and reduce permeability. However, these chemicals are expensive and to reduce costs, this study is to find replacement materials.

polymer-modified (or polymer- cement) mortar or concrete, which is made by the modifying ordinary cement mortar or concrete with polymer additives such as latexes, redispersible polymer powders, water-soluble polymers, liquid resins, and monomers. Polymer-modified mortars and concretes have a monolithic co-matrix in which the organic polymer matrix and the cement gel matrix are homogenized. The properties of polymer modified mortar and concrete are characterized by such a co-matrix. In the systems modified with the latexes, redispersible polymer powders, and water-soluble polymers, the drainage of water from the systems along with the cement hydration leads to film or membrane formation. In the systems modified with the liquid resins and monomers, the addition of water induces the hydration of the cement and the polymerization of the liquid resins or monomers [2].

In 2020, the total value of intermediate rubber production in Thailand came to around THB140 billion, including goods sold on both domestic and export markets. Thailand is in the fortunate position of its production being overwhelmingly of fresh rubber (92% of upstream production is of fresh latex rubber).

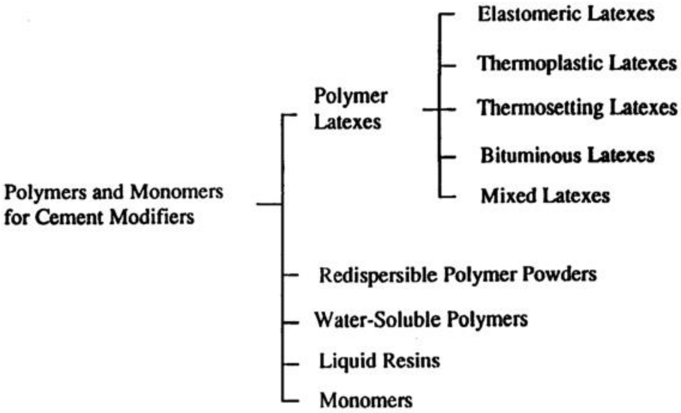

Figure 2. Polymers and monomers for cement modifiers

Over the years 2004 to 2011, the price of rubber rose to historic highs because Global demand for rubber rose sharply through this period, especially from China and India, following this boom period, though, demand slackened substantially and world commodity markets deflated as speculative pressure had faded, leaving global stocks of rubber at around 3.0 - 3.1 million tones at the end of 2018-2019. Nowadays the price of rubber is very low. Therefore, this study, in finding replacement materials, also wanted to increase the value of rubber latex as well [3].

Natural Rubber Latex (NRL) is a natural renewable resource, which can be employed for modification of cement [4]. Natural Rubber latex obtained from *Heveabrasiliensis* tree by natural polymerization process and is a dispersion of polyisoprene [5].

Natural Rubber Latex represents an eco-friendly, sustainable and non-petroleum based material. Low cost, increasing availability and the ecological aspect as a renewable material make natural rubber attractive for new applications [6].

Natural rubber latex is a good choice to use in cement mix because it is a natural polymer, not harmful to the environment, low costs and easy to provide locally. However, the appropriate mixing ratio of cement, Natural rubber latex, and other binder materials is not well studied and determined.

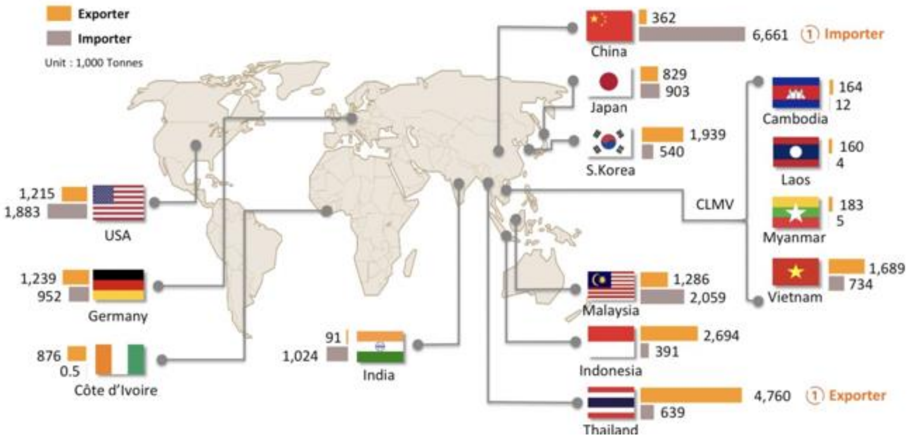

Figure 3. Major Natural Rubber Exporters and Importers (2019)

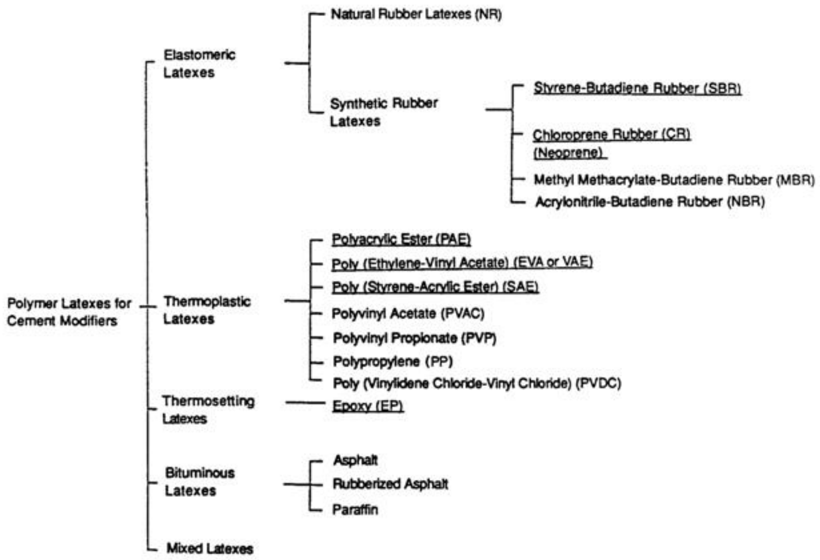

Figure 4. Commercially available polymer latex for cement modifiers

2. Literature review

Brief description of the various past studies conducted on the effect of natural rubber latex modification of concrete is presented below.

Bala M., Ismail M. (2012) discovered the concrete with natural rubber latex improves the plain concrete from porous to an impermeable structure by forming a lining of latex film across voids pores and micro cracks [7]. Muhammed Ijas M. et al. (2016) investigated effect of natural rubber latex (NRL) – clay power mixture on the strength of Portland concrete. The strength of concrete mainly depends upon the porosity. Concrete has high compressive strength and low tensile strength. Earlier natural rubber latex was added to the concrete, which were able to reduce the porosity that a polymer latex added to concrete can reduce the porosity and improve the strength of the test concrete [8]. Thanarit R. (2011) studied filtration properties of Natural Rubber Latex containing mud and found that Natural Rubber Latex in bentonite could reduce the fluid filtration loss volume. He also found that the thermal stability of the Natural Rubber Latex mud could be used in subterranean well formation having downhole temperature up to 80ºC [17]. Therefore, this study aims to determine the optimum material mixing ratio in order to improve the compressive strength of the mixed API class G cement.

3. Methodology

3.1 Principles of latex modification

Latex modification of cement mortar and concrete is governed by both cement hydration and polymer film formation processes in their binder phase. The cement hydration process generally precedes the polymer formation process. In due course, a co-matrix phase is formed by both cement hydration and polymer film formation processes [2].

3.2 Mechanism of Polymer-Cement Co-matrix Formation

It is believed that a co-matrix phase which consists of cement gel and polymer films is generally formed as a binder according to a three-step simplified model shown in Figure 5 and Figure 6

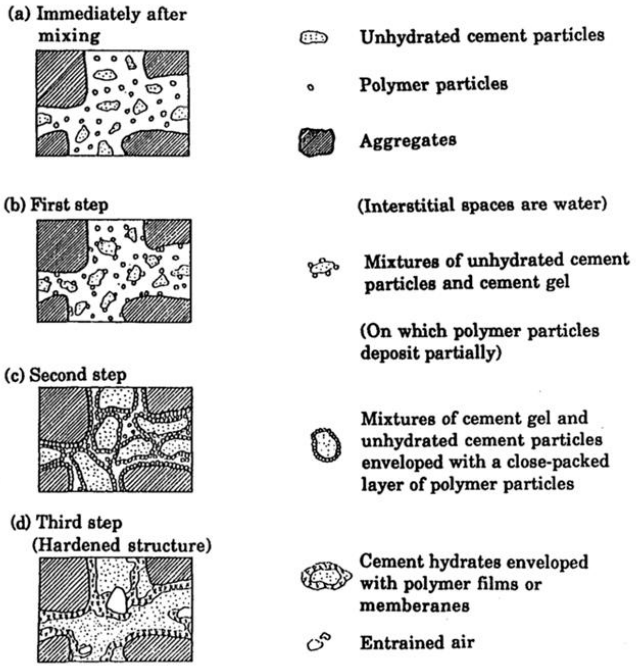

Figure 5. Simplified model of formation of polymer -cement co-matrix

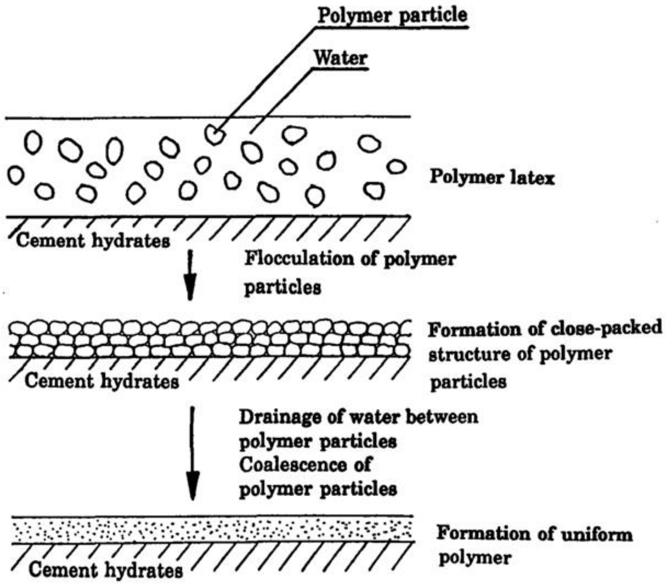

Figure 6. Simplified model of process of polymer film formation on cement hydrates

Grosskurth proposed a similar model indicating the formation of the polymer cement co-matric. Sugita et al., have recently investigated the microstructures and composite mechanism of latex-modified pastes and mortars, and found the interfacial layer of cement hydrates with a large amount of polymer particles on the aggregates and cement particles. As a result, both the particle dispersion of the polymer and the formation of polymer films are necessary for explaining the composite mechanism of the latex-modified systems [2].

3.3 Material

3.3.1 API Class G Cement

API Class G (HSR) cements are used in the production and exploration of oil and gas onshore and in deep water offshore wells to depths of up to 10,000 feet (3,048 meters). A typical well can be thousands of meters deep, less than a meter wide, and is constructed by using a metal casing surrounded by a special cement slurry mix that fills the annulus between the outer face of the tubing and the wall formation of the hole.

3.3.2 Natural Rubber Latex

Natural Rubber latex in Hevea Brasiliensis is located in latex vessels to be founded in various parts of the tree. The lowest occurring is in the wood and the highest in the secondary phloem. There are the vessels aligned to spirals in concentric circles close to cambium. It is obtained from them by tapping based on cutting of the tree bark by special knife under approximate angle of 30°. It is collected into special bowls. In this study used natural rubber latex (60% Concentrated Latex - High Ammonia)

3.3.3 Water

Water is an important ingredient of concrete as it actively participates in the Chemical reaction with cement. The quantity and quality of water is to be carefully selected for the test conducted for the investigation.

3.3.4 Surfactants

Polymer latex is a colloidal dispersion of small polymer particles in water, which is generally produced by the emulsion polymerization of monomers with surfactants. Surfactants are a large group of surface-active substances with numerous applications because of their relatively complex behaviors [10-13]. Surfactants have a hydrophobic part and a hydrophilic part. depending on the nature of the hydrophilic part the sur- factants are classified as anionic, nonionic, cationic, and zwitterionic [14]. Ouyang et al. (2008) studied the effect of the synthetic surfactant combining nonionic and anionic surfactant on the compressive strength of cement mortar. The results indicated that the suitable dosage of this surfactant could improve not only the fluidity but also the compressive strength of mortar. On the other hand, an excess amount of surfactant may have an adverse effect on the strength of the latex modified mortar and concrete because of the reduced latex film strength [16]. Siriphun S. et al. (2005) Mixed concrete with natural rubber latex Can be mixed with a mixer like general concrete Importantly, water must be mixed with non-ionic surfactants [9].In this study used Lutensol XL 80 at a ratio of 4% by weight of the total cement. When the concrete is well blended, the natural latex is then mixed in the last order.

3.4 Cement Preparation

In this study the API class G cement had been prepared as cement slurry at water/cement ratio (W/C) of 0.5 wt.% and were mixed with natural rubber latex (60% concentrated Latex - High Ammonia) at polymer (NRL) /cement ratio (P/C) of 0, 0.05, 0.10, 0.15, 0.20 and 0.25 by Cement mixer equipment

The cement slurry samples were casted in the cylindrical mold and cut in size 1.46”x2”, moist cured for 7 days, and air cured for 28 days at room temperature, respectively. The formulations of the cement are shown in Table 1.

Table 1. Compositions of cement sample.

Sample	API class G cement (g.)	Water (g.)	NRL (g.)	Surfactant (g.)
No.1	1500	750	0	0
No.2	1500	750	75	60
No.3	1500	750	150	60
No.4	1500	750	225	60
No.5	1500	750	300	60
No.6	1500	750	375	60

3.5 Testing

All of cement sample was tested in the Suranaree University of Technology laboratory. Base on API (American Petroleum Institute) RP 10B-2, Recommended Practice for Testing Well Cements [18].

3.5.1 Porosity

Porosity is define as the ratio of void-space volume (ie. Pore volume) to bulk volume of a material. Porosity in clean and dried core samples is determinate by a combination of two of the following three physical properties such as Grain volume, Pore volume, and Bulk volume Grain volume and pore volume can be determined from Helium injection and the application of Boyle’s Law. Bulk volume measured by the summation of pore volume and grain volume [19].

3.5.2 Pemeability

To determine the permeability (using Overburden poro-perme cell) of a core sample air (or nitrogen) at a known initial pressure (upstream pressure) is made to flow through the length of the sample. The sample is sealed along its length so that no air may bypass the sample. The flow rate of air from the other end of the sample is measured. The permeability for that sample is then calculated using Darcy’s Law through knowledge of the upstream pressure and flow rate during the test, the atmospheric pressure, the viscosity of air (or nitrogen), and the length and cross sectional area of the sample [19].

Figure 7. Cement sample

4. Result and Discussion

4.1 Porosity Test

Porosity test results of cement samples by using a Porosimeter (Figure 8). In this testing, including the use of principles Boyle's Law for determining porosity is shown in Table 2 and Figure 10

4.2 Permeability Test

Permeability Test Results of the cement sample using a permeameter (Figure 9) for testing and Darcy's Law Principle of Coefficient Calculation in the permeability of cement. This test used an external pressure (Overburden pressure) of 600 psi and the pressure that flows through the sample 40 psi as shown in Table 3 and Figure 11.

Based on the porosity measurement results of a set of natural rubber latex cement samples. It was found that the porosity of all samples tended to improve with the addition of natural rubber latex, (%porosity are decrease), When natural latex was not added, the result was 18.01. When adding up to 10%wt., the porosity was continuously decreasing. But if adding more than 10% wt., founded the porosity will gradually increase. However, the porosity was still less than when natural latex was not added.

Figure 8. Porosimeter

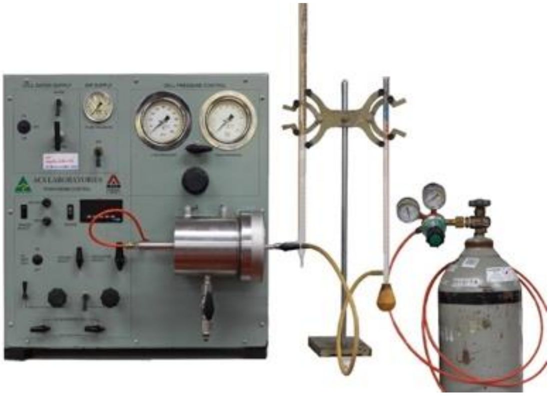

Figure 9. Permeameter

Table 2. Porosity results of cement samples

Ratio	Sample	Diameter (mm)	Length (mm)	P_{os} (psi)	P_s (psi)	Porosity (%) Result	Average
0.00	1/1	37.3	51.1	50.01	12.01	17.91	18.01
	1/2	37.4	49.8	50.08	11.81	18.11	
0.05	2/1	37.3	50.6	50.01	12.39	13.96	15.34
	2/2	37.3	51.7	50.04	12.28	16.72	

Table 2. Porosity results of cement samples (cont.)

Ratio	Sample	Diameter (mm)	Length (mm)	P_{os} (psi)	P_s (psi)	Porosity (%)	
						Result	Average
0.10	3/1	37.5	53.8	50.01	13.44	12.73	11.44
	3/2	37.4	51.9	50.06	13.29	10.14	
0.15	4/1	37.3	50.6	50.02	12.44	13.58	12.50
	4/2	376	50.7	50.05	12.94	11.43	
0.20	5/1	37.4	53.2	50.01	12.86	15.17	14.09
	5/2	37.8	52.7	50.04	13.2	13.01	
0.25	6/1	37.8	49.2	50.08	12.10	15.46	16.28
	6/2	37.8	50.1	50.05	12.08	17.09	

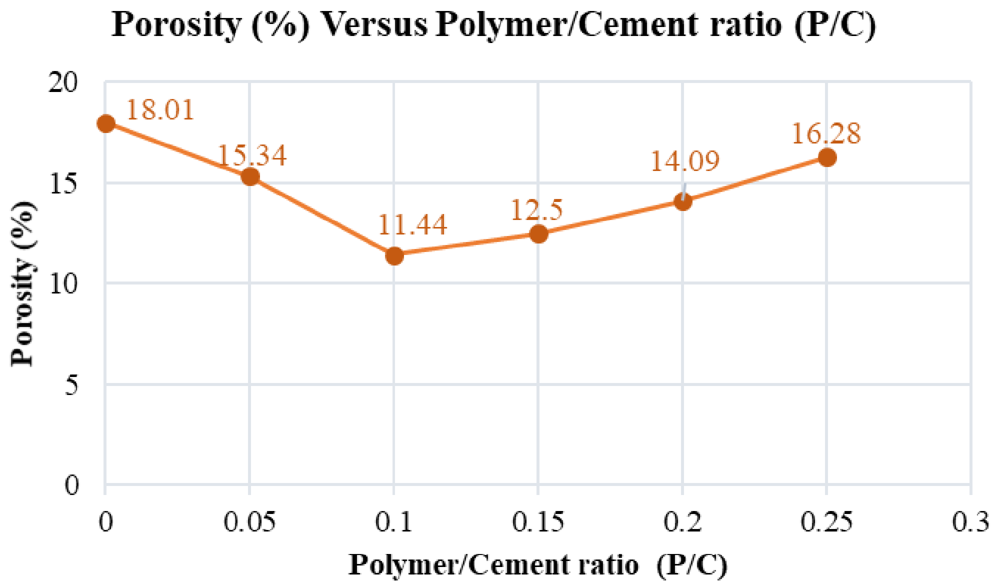

Figure 10. Porosity (%) Versus Polymer/Cement ratio (P/C)

Table 3. Permeability results of cement samples

Ratio	Sample	Diameter (mm)	Length (mm)	P_c psi	P_1 psi	V cm^3	Time sec	Q cm^3/sec	k (millidarcy)	
									Result	Average
0.00	1/1	37.3	51.1	600	40	10	27.58	0.363	0.446	0.471
	1/2	37.4	49.8	600	40	10	24.05	0.416	0.496	
0.05	2/1	37.3	50.6	600	40	10	20.5	0.049	0.062	0.064
	2/2	37.3	51.7	600	40	10	19.0	0.053	0.066	
0.10	3/1	37.5	53.8	600	40	10	35.0	0.029	0.035	0.027
	3/2	37.4	51.9	600	40	10	26.3	0.038	0.047	
0.15	4/1	37.3	50.6	600	40	10	25.4	0.039	0.048	0.048
	4/2	376	50.7	600	40	10	24.8	0.040	0.048	
0.20	5/1	37.4	53.2	600	40	10	15.7	0.064	0.081	0.077
	5/2	37.8	52.7	600	40	10	17.0	0.059	0.073	
0.25	6/1	37.8	49.2	600	40	10	9.1	0.110	0.127	0.124
	6/2	37.8	50.1	600	40	10	9.6	0.104	0.122	

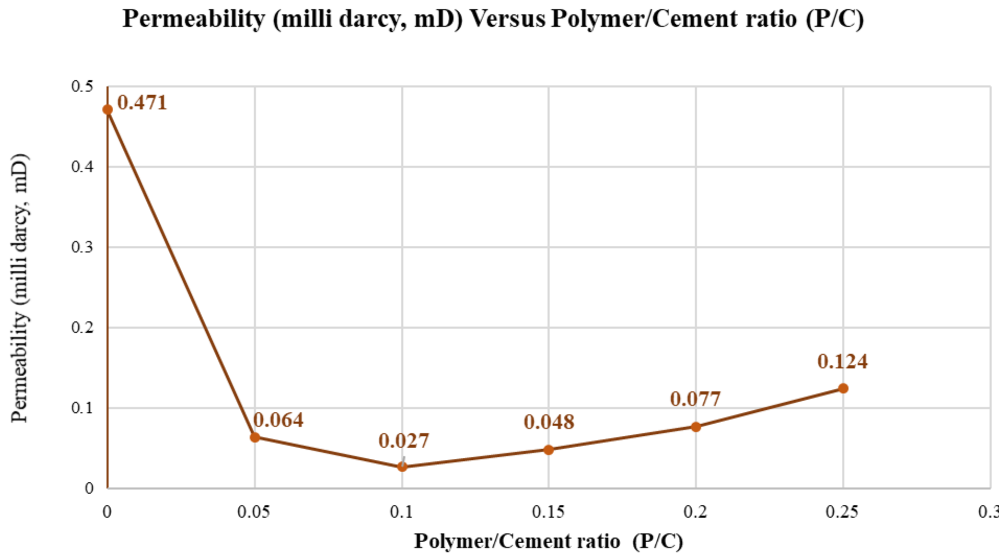

Figure 11. Permeability (milli darcy, mD) Versus Polymer/Cement ratio (P/C)

Based on the permeability measurement results of a set of natural rubber latex cement samples. It was found that the permeability decreased sharply when natural rubber latex was added. It shown that adding natural rubber latex and cement had formation of polymer films.

Results of the tests showed natural rubber latex cement decrease porosity and permeability by forming a lining of latex film across voids pores and micro cracks. the porosity and permeability values of the cement samples decreased until the P/C ratio reach 10 wt.% and then they increased steadily.the porosity and permeability values began to increase again after adding more than 10% wt. because if the P/C ratio is greater than 10 %wt., the hydration reaction of the mixed cement will take place rather than the polymer coalescence reaction and resulted in the higher polymer flocculant and dispersion. Therefore, the optimal P/C ratio for using the natural rubber latex as a fluid loss prevention additive for the API Class G Cement is 10 % wt.

5. Conclusions

Based on laboratory experiments and data analysis in this study. Some conclusions were drawn as follows:

1. Natural latex can be used as an additive for class G cement in terms of its use as a protective loss fluid.
2. From the test of cement added with natural rubber latex. It was found that natural latex binds to cement, has better porosity and better permeability.
3. The optimum ratio for use is P/C = 0.10 because it is low porosity and permeability.

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